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MEMO

To: Dolly Potter
From: Bill Stark WTS
Subject: Calciner BACT
Date: April 21, 1997

Enclosed please find a hardcopy and electronic copy of the calciner BACT analysis. The spreadsheets are in Excel and the text is in WordPerfect.

The cost information for the catalytic oxidation, carbon adsorption, and condensation alternatives was developed based on TRC trona plant file information and information presented in the OAQPS Cost Control Manual. The flare spreadsheet is taken directly from the EPA bulletin board. In all cases the control alternatives are in excess of $5,000 per ton, which is considered to be unreasonable.

The text write-up is virtually identical to that we prepared for OCI. You can leave it as it is or you may want to edit it further.

Let me know if you have questions or if TRC can be of further assistance.

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Volatile Organic Compound Control Technologies

The following sections address VOC emissions from calciner operation. The VOC emissions from calciner operations result from small amounts of oil shale that is mined with the trona ore and therefore are unique to the trona industry.

Identification of Technically Feasible VOC Control Options

Combustion and removal are the two principal categories of control methods for VOC emissions. Applicable VOC emissions control technologies considered in identification of technically feasible control options for the calciner are listed below and are described in the following subsections.

- Combustion (including flaring and thermal and catalytic incineration)
- Absorption
- Adsorption
- Condensation

Combustion Devices

The process most often used to control the emissions of organic compounds from process industries is incineration (also referred to as oxidation). At sufficiently high temperatures and adequate residence times, any hydrocarbon can be converted to carbon dioxide and water by the combustion process. Combustion devices are often relatively simple devices capable of achieving very high destruction efficiencies. They consist of burners, which ignite the fuel (an organic) and a chamber, which provides adequate residence time for the oxidation process. Equipment used to abate waste gases by combustion can usually be divided in three categories; flares, thermal incinerators and catalytic incinerators.

Flares

Flaring is a high-temperature oxidation process used to burn combustible components, mostly hydrocarbons, of waste gases from industrial operations. Natural gas, propane, ethylene, propylene, butadiene and butane constitute over 95 percent of the waste gases flared. During a combustion reaction, Carbon dioxide (CO_2) and water are formed when gaseous hydrocarbons react with atmospheric oxygen. Several intermediate products are also formed, and eventually, most are converted to CO_2 and water, but some quantities of stable intermediate products such as carbon monoxide, hydrogen, and hydrocarbons will escape as emissions. Flares are used extensively to dispose of (1) purged and wasted products from refineries, (2) unrecoverable gases emerging with oil from oil wells, (3) vented gases from blast furnaces, (4) unused gases from coke ovens, and

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(5) gaseous wastes from chemical industries. Gases flared from refineries, petroleum production, chemical industries, and to some extent, from coke ovens, are composed largely of low molecular weight hydrocarbons with high heating value.

Flaring systems are considered technically feasible control options for the control of VOC. However, due to the large volume of the exhaust stream, supplemental fuel and air would be required to combust the VOCs present in the exhaust stream and a steam assisted flare would be needed to achieve the desired removal. Costs indicate that this option is not economically feasible.

Thermal Incineration

Thermal incineration is also a high-temperature oxidation process, but unlike flaring, the combustion waste gases pass over or around a burner flame into a residence chamber where combustion is completed. Thermal incinerators, also referred to as thermal oxidizers or afterburners, can be used over a fairly wide, but low, range of organic vapor concentrations. The concentration of the organics in the vapor stream must be substantially below the lower flammable level (lower explosive limit), Combustion in thermal oxidizers is conducted at elevated temperatures to ensure high chemical reaction rates for the organics. To achieve this temperature, it may be necessary to preheat the feed stream with auxiliary energy.

Thermal recuperative and thermal regenerative are the two main types of thermal incinerators in use. The thermal recuperative type is the most common and nearly always employs a heat exchanger to preheat a gaseous stream prior to incineration. Regenerative type incinerators are newer and employ ceramics to obtain a more complete transfer of heat energy. There are no known applications of thermal recuperative incinerators on calciners and, single catalyst incinerators can achieve the same removal efficiency at potentially lower annual costs, therefore, this option is not evaluated further.

Catalytic Incineration

Catalytic incinerators are very similar to thermal incinerators except that the combustion within the chamber takes place under the presence of a catalyst. The presence of the catalyst in the combustion chamber reduces the combustion temperature needed to ensure complete combustion, thus reducing supplemental fuel consumption and associated operating costs. Catalysts used are typically composed of inert substrate coated with a metal alloy and require extremely clean exhaust streams to operate efficiently. Although catalytic incinerators can achieve overall VOC control efficiencies of 95% for most applications their cost makes them economically infeasible for this application.

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Absorption

Absorption is a removal control method for VOC emissions. The process of absorption refers to the contacting of a mixture of gases with a liquid so that part of the constituents of the gas will dissolve in the liquid. Referred to as scrubbing, gas absorption as applied to the practice of air pollution is concerned with the removal of one or more pollutants from a contaminated gas stream by treatment with liquid. The necessary condition is the solubility of these compounds in the liquid.

Absorption can be classified as physical or chemical. Physical absorption occurs when the absorbed compound simply dissolves in the solvent. Chemical absorption occurs when a reaction occurs between the absorbed compound and the liquid. The absorption rate is determined by the physical properties of the gaseous/liquid system (i.e. diffusivity, viscosity, density) and the scrubber operating conditions (i.e. temperature, flow rates of the gaseous and liquid streams). It is enhanced by lower-temperatures, greater contacting surface area, higher liquid/gas ratios and higher concentrations in the gas stream.

While absorption can be considered a "technically feasible" control technology, no known applications of absorption have been applied to calciner operations at trona plants. Therefore, the application of this control method is considered "technically unreasonable" for this application. Additionally, the cost of developing absorption applications for the process would be prohibitive. Therefore, the scrubbing option has not been further evaluated.

Carbon Adsorbtion

In Adsorption, VOCs are selectively removed and adsorbed on the surface of an adsorbent material. The adsorbed substance does not penetrate the structure of the solid but remains entirely upon the surface. Activated carbon is the most widely used adsorbent, however other substances such as silica gel or alumina can also be used in specialized applications. Adsorbed VOCs are removed from the carbon bed by heating to a sufficiently high temperature (usually via steam) or by reducing the pressure to a sufficiently low value (vacuum desorption).

As with absorption methods, carbon adsorption systems have not been applied to trona calciners. Although carbon adsorption can be considered a "technically feasible" control technology, the application of this control method is considered "technically unreasonable" for this application., and even if feasible, is shown to be cost-prohibitive.

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Condensation

Condensation is a separation technique in which one or more volatile components of a vapor mixture are separated from the remaining vapors through saturation followed by a phase change. The phase change from gas to liquid can be accomplished in two ways; the system pressure may be increased at a given temperature or the system temperature may be reduced at constant pressure. When condensers are used to control emissions, they are usually operated at the pressure of the emission source, which is typically close to atmospheric. Depending upon the temperatures required for condensation, a refrigeration unit may be necessary to supply the coolant.

Surface and contact condensers are the two most common types of condensers. Surface condensers are also referred to as shell and tube heat condensers where the coolant typically flows through the tubes and the vapor condenses on the shell outside the tubes. The condensed vapors form a film on the cool tubes and are drained to a collection tank for storage or disposal. In contact condensers, the vapor mixture is cooled by spraying a cool liquid directly into the gas. The coolant does not contact the vapors of the condensate, as it does in surface condensers.

Condensers generally require inlet concentrations of thousands of ppm in order to achieve removal efficiencies of greater than 80%. The VOC concentration of the vent stream will be fairly low, so a roto-concentrator type device would have to be used in order to concentrate the stream and make adsorption feasible. As with other technologies described above, there are no applications of condensers to calciners at trona plants. Also, a cost estimate indicates that this option is cost prohibitive.

BACT Proposal for Calciner VOC Control

While most of the control options discussed above are considered technically feasible, all are not practical and would be too costly to warrant consideration for the purpose of VOC control for the calciner exhaust stream. Also, there are no calciners with add-on controls listed in the BACT/LAER Clearinghouse. The VOC concentrations present are quite low given the large volume of the exhaust stream. Since there is so little energy available in the exhaust stream, energy requirements are very high for the conventional combustion based options that would normally be applied in such a situation. A cost analysis performed for several technically feasible control options indicates that all add-on options are cost prohibitive. Therefore, the proposed BACT for the calciner is no add-on controls and efficient combustion.

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COST COMPONENT:	Catalytic Oxidation	Carbon Adsorption	Condensation
DIRECT COSTS			
Purchased Equipment Costs			
Basic and Auxiliary Costs (Base + 35%)	6,376,750	7,900,500	9,056,250
Structural Support (10% of Basic and Auxiliary Equipment)	637,675	790,050	905,625
Sales Tax (4% of Basic and Auxiliary equipment costs)	255,070	316,020	362,250
Freight (4% of Basic and Auxiliary equipment costs)	255,070	316,020	362,250
Subtotal-Purchased Equipment Costs (PEC)	*7,524,565*	*9,322,590*	*10,686,375*
Direct Installation Costs			
Installation/Foundation (25% of PEC)	1,881,141	2,330,648	2,671,594
Subtotal-Direct Installation Costs	*1,881,141*	*2,330,648*	*2,671,594*
TOTAL DIRECT COSTS (TDC)	9,405,706	11,653,238	13,357,969
INDIRECT INSTALLATION COSTS			
Engineering Costs (5% of PEC)	376,228	466,130	534,319
Construction Fees and Field Expenses (15% of TDC)	1,410,856	1,747,986	2,003,695
Contingency (15% of TDC)	1,128,685	1,398,389	1,602,956
OTHER INDIRECT COSTS			
Start-up and Performance Tests (1% of TDC)	94,057	116,532	133,580
TOTAL INDIRECT COSTS	*3,009,826*	*3,729,036*	*4,274,550*
TOTAL CAPITAL INVESTMENT (TCI)	**12,415,532**	**15,382,274**	**17,632,519**
DIRECT ANNUAL COSTS			
Direct Labor (2,000 hr @ $12.50/hr)	25,000	25,000	25,000
Maintenance Labor (1,000 hr @ $15.00/hr)	15,000	15,000	15,000
Replacement Parts (1.5% of Purchased Equipment Costs)	112,868	139,839	160,296
Catalyst Replacement Cost (assumes replacement every 5 years)	995,761	N/A	N/A
Fuel Usage ($2.05 per Mscf)	5,863,000	N/A	N/A
Electricity ($0.06/kW*hr)	N/A	489,925	117,300
Steam ($0.003/lb)	N/A	65,700	N/A
Water ($1.95/1000 gal)	N/A	512,460	N/A
Waste Disposal ($2,000/ton)	N/A	N/A	1,680,000
TOTAL ANNUAL DIRECT COSTS	*7,011,629*	*1,247,924*	*1,997,596*
INDIRECT ANNUAL COSTS			
Overhead (60% of labor)	24,000	24,000	24,000
Property Tax (1% of TCI)	124,155	153,823	176,325
Insurance (1% of TCI)	124,155	153,823	176,325
Administration (2% of TCI)	248,311	307,645	352,650
TOTAL INDIRECT ANNUAL COSTS	*520,621*	*639,291*	*729,301*
TOTAL ANNUAL INVESTMENT	**7,532,251**	**1,887,215**	**2,726,896**
CAPITAL RECOVERY FACTOR			
Equipment Life (years) = 10			
Interest Rate (%) = 10			
Capital Recovery Factor	0.16	0.16	0.16
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT	**12,415,532**	**15,382,274**	**17,632,519**
TOTAL ANNUAL CAPITAL REQUIREMENT	**2,020,571**	**2,503,394**	**2,869,611**
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	***$9,552,821***	***$4,390,609***	***$5,596,508***
UNCONTROLLED TONS OF VOC EMITTED PER YEAR (BASELINE EMISSIONS)	884	884	884
TONS OF VOC EMITTED AFTER CONTROL	44	44	44
TONS OF VOC REMOVED PER YEAR	***840***	***840***	***840***
COST-EFFECTIVENESS			
ENVIRONMENTAL BASIS ($ per ton of VOC removed)	**$11,375**	**$5,228**	**$6,664**

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TOTAL ANNUAL COST SPREADSHEET PROGRAM--FLARES [1]

COST BASE DATE: March 1990 [2]

VAPCCI (Third Quarter 1995): [3] 109

INPUT PARAMETERS

-- Vent flowrate (acfm):	264000
(lb/hr):	417020
-- Vent heat content (BTU/scf):	0
-- Fuel heat content (BTU/scf):	1000
-- Inlet gas temperature (oF):	338
-- Vent stream density (lb/scf):	0.0845
-- System pressure (psig):	10.00
-- Liquid density (lb/ft3):	50

DESIGN PARAMETERS

-- Gas velocity, max. (ft/sec):	60.00
-- Auxil. fuel requirement (scfm):	113105.14
-- Total gas flowrate (scfm):	377105
-- Flare tip diameter (in):	154.59
-- Heat release rate (BTU/hr):	493749
-- Flare height (ft):	4.0
-- KO drum max. velocity (ft/sec):	4.84
-- KO drum min. diameter (in):	408.1
-- KO drum height (in):	1224.4
-- KO drum thickness (in):	0
-- No. of pilot burners:	1

CAPITAL COSTS

Equipment Costs ($):

-- Flare/self-supported:	2,231,888
-- Flare/guy-supported:	0
-- Flare/derrick-supported:	0

Minimum flare cost:	2,231,888
Knockout drum cost:	96,652

-- Total equipment (base):	2,328,540
' ' (escalated):	2,772,379
Purchased Equipment Cost ($):	3,271,408
Total Capital Investment ($):	6,281,103

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Cost Effectiveness of Flare

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ANNUAL COST INPUTS

Operating factor (hr/yr):	8760
Operating labor rate ($/hr):	16
Maintenance labor rate ($/hr):	17.20
Operating labor factor (hr/yr):	630
Maintenance labor factor (hr/sh):	1
Steam price ($/1000 lb):	5
Natural gas price ($/mscf):	3
Annual interest rate (fraction):	0
Control system life (years):	15
Capital recovery factor:	0.1098
Taxes, insurance, admin. factor:	0

ANNUAL COSTS

Item	Cost ($/yr)
Operating labor	9,853
Supervisory labor	1,478
Maintenance labor	9,419
Maintenance materials	9,419
Natural gas	500,066
Steam	6,794,757
Overhead	18,102
Taxes, insurance, administrative	251,244
Capital recovery	689,631
Total Annual Cost	8,283,970

CONTROL COST EFFECTIVENESS

Pollutant	VOC
Uncontrolled Emissions, lb/hr (average hourly)	201.88
Operating Hours, hr/yr	8760
Uncontrolled Emissions, ton/yr	884.23
Control Efficiency, %	98
Emissions After Control, ton/yr	17.68
Pollutants Removed, ton/yr	866.55
Cost Effectiveness, $/ton	9559.72

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NOTES:

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[1] Data used to develop this spreadsheet were taken from Chapter 7 of the 'OAQPS Control Cost Manual' (4th edition).

[2] Base equipment costs reflect this date.

[3] VAPCCI = Vatavuk Air Pollution Control Cost Index (for flares) corresponding to year and quarter shown. Base equipment cost, purchased equipment cost, and total capital investment have been escalated to this date via the VAPCCI and control equipment vendor data.

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